2.27 DETAILED RESULTS FOR ANGLE TRACKING

No errors were found in the Angle Track Functional Element for ESAMS 2.6.2. The overall code quality and internal documentation are good with only one minor discrepancy uncovered.

Table 2.27-1 summarizes the desk-checking and software testing verification activities for each design element in the Angle Track FE. The two results columns contain checks if no discrepancies were found. The test case results column lists the number of the relevant test case in Table 2.5-5. More detailed information on the results is recorded in these tables.

TABLE 2.27-1. Verification Results Summary.

Design Element	Code Location	Desk Check Result	Test Case ID	Test Case Result
27-1: Two Channel Resolver	RESLV2 51-66	√	27-1, 2	√
27-2: Two Channel Range Gate and Normalization	DEMOD2 73-87	√	27-3	√
27-3: Two Channel Angle-Demodulator	DEMOD2 89-135	√	27-4, 5, 6	27-6
27-4: Two Channel Error Angles	DEMOD2 114-115, 130-131	√	27-4, 5, 6	27-6
27-5: Antenna Pedestal Dynamics	SVOEXC 145-177 181-242 ANTPOI 124-139 142-160	√	27-11, 12, 13, 14, 15, 17, 18	27-12, 13
27-6: Three Channel Composite Signals	SUMDIF 87-103	√	27-7	√
27-7: Three Channel Normalization	SUMDIF 105-141	√	27-8	√
27-8: Three Channel Error Angles	SUMDIF 143-144	√	27-9, 10	√
Initialization	SVOEXC 134-143 ANTPOI 102-121	√	27-14, 16	√

2.27.1 Overview

The Angle Tracking FE models the portion of the radar that extracts and processes target off-boresight error measurements to reposition the antenna pointing servos. The purpose is to maintain small error measurements in an effort to sustain optimum track on the target.

Five subroutines implement Angle Track in ESAMS 2.6.2. Two subroutines RESLV2 and DEMOD2, which compute the measured off-boresight angle error, are dedicated to the two-channel systems. Subroutines SVOEXC and ANTPOI compute the response of the antenna pedestal to the generated repositioning commands, together they are used for both two- and three-channel systems. These subroutines are described in Table 2.27-2.

TABLE 2.27-2. Subroutine Descriptions.

RESLV2	Simulates the operation of the two-channel resolver. the routine receives as input, the azimuth and elevation difference channel signals computed by the antenna response modules, forms the modulated quadrature signal Δ, and combines it with the sum channel signal to form the two-channel main and auxiliary channel signals ∑+Δ and ∑-Δ.
DEMOD2	Simulates the operation of the two-channel monopulse demodulator. The routine receives as input the main and auxiliary channel signals and produces the azimuth and elevation off-boresight error angles at each time step.
ANTPOI	Initializes the antenna pedestal servo constants and difference equations.
SVOEXC	Simulates the motion of the antenna pedestal as it is repositioned during angle track update. The routine receives as input the azimuth and elevation off-boresignt error angles and updates a set of discrete-time difference equations.
SUMDIF	Combines the sum and difference channel signals, detects the phase of the difference channels with respect to the sum channel and computes the azimuth and elevation off-boresight error angles.

2.27.2 Verification Design Elements

Design elements defined for angle track FE are listed in Table 2.27-1, they are fully described in Section 2.27.2 of ASP-II. ADesign elements 27-1 through 27-4 direct the generation of off-boresight error angles for a two-channel monopulse system. Design elements 2.27-6 through 2.27-8 direct the generation of off-boresight error angles for a three-channel monopulse system. Design element 27-5 simulates the antenna pedestal dynamics in response to input commands.

TABLE 2.27-3. Angle Track Design Elements.

Subroutine	Design Element	Description
RESLV2	27-1 Two Channel Resolver	Compute the resolved component of the main and auxiliary channel signal.
DEMOD2	27-2 Two Channel Range Gate and Normalization	Compute the normalized delta signal which is given by the ratio of the difference channel to the sum channel signal for a two channel system.
DEMOD2	27-3 Two Channel Angle Demodulator	Compute the separate difference channel signals by demodulating the combined signal from the resolver output.
DEMOD2	27-4 Two Channel Error Angles	Compute off-boresight error angles for two-channel system.
SVOEXC ANTPOI	27-5 Antenna Pedestal Dynamics	Compute the antenna position using equation [2.27-26] and rate difference equation output using equation [2.27-30]. Compute difference equation coefficients given by equations [2.27-27] and [2.27-31].
SUMDIF	27-6 Three Channel Composite Signal	Compute the three channel composite sum and difference channel signal. Composite signals are composed of signal components from all signal generators.

TABLE 2.27-3. Angle Track Design Elements. (Contd.)

Subroutine	Design Element	Description
SUMDIF	27-7 Three Channel Normalization	Normalize the three channel composite sum and difference channel signals.
SUMDIF	27-8 Three Channel Error Angles	Compute the off-boresight error angles for three channel system.
SVOEXC ANTPOI	Initialization	Difference equations, position equations and rate difference equations are initialized.

2.27.3 Desk Checking Activities and Results

The code implementing this FE was manually examined using the procedures described in Section 1.1 of this report. No discrepancies were discovered.

Except as noted in Table 2.27-4 below, overall code quality and internal documentation were evaluated as good. Subroutine I/O were found to match the ASP II descriptions.

TABLE 2.27-4. Code Quality and Internal Documentation Results.

Subroutine	Code Quality	Internal Documentation
DEMOD2	Possible overflow condition if SUM = 0. The possibility is, however, very unlikely.	OK

2.27.4 Software Test Cases and Results

All subroutines implementing the angle tracking functional element were tested by off-line and integrated code methods. Off-line testing of the two-and three-channel monopulse systems was performed using a variety of input signal voltages and two different reference frequencies. For integrated testing, the entire ESAMS model was run in debug mode to perform input-output verification, array bound checks, and special case overflow condition checks. Numerical results in both implementations were compared to pre-calculated values. Unless otherwise indicated, the standard ESAMS data files for the systems under consideration were used as input for all test cases.

TABLE 2.27-5. Software Test Cases for Angle Tracking.

Test Case ID	Test Case Description
27-1	Objective: Check two-channel resolver output on three sets of single target signals. Procedure: Set resolver scan frequencies and monopulse signal values for each case at: Case 1: RESCFQ = 120.0 SGSV = (5.0, 0.0) SGDVA = (0.0, 0.0) SGDVE = (3.0, 0.0) Case 2: RESCFQ = 120.0 SGSV = (3.0, 5.0) SGDVA = (1.5, 3.0) SGDVE = (0.0, 0.0) Case 3: RESCFQ = 120.0 SGSV = (4.5, -4.5) SGDVA = (-1.5, 1.5) SGDVE = (-1.5, 1.5) 1. Stop in subroutine RESLV2. 2. Stop on line 66. 3. Examine variables SGDVA and SGDVE. 4. Compare to pre-calculated values. 5. Repeat steps 1-4 for all three cases. Verify: ESAMS values match the independently calculated values. Result: OK
27-2	Objective: Check the Q and I channel sinusoidal reference signals over a complete resolver scan period. Procedure: Set resolver scan frequencies and monopulse signal values at: RESCFQ = 34.7 SGSV = (5.0, 0.0) SGDVA = (0.0, 0.0) SGDVE = (3.0, 0.0) 1. Stop in subroutine RESLV2. 2. Stop on line 66. 3. Examine variables REFCHI and REFCHQ. 4. Compare to pre-calculated values. 5. Go to 1. (Repeat process over one complete scan period - 20 iterations) Verify: ESAMS values match the independently calculated values. Result: OK

TABLE 2.27-5. Software Test Cases for Angle Tracking. (Contd.)

Test Case ID	Test Case Description
27-3	Objective: Check normalized delta signal calculation. Procedure: Set scan frequency and monopulse signals at: RESCFQ = 34.7 Target range = 5000.0 m, speed = 500.0 m/s, no range gating. 1. Stop in subroutine DEMOD2 2. Stop on line 87 3. Examine variable SIGNRM 4. Compare to pre-calculated value 5. Go to 1 (Repeat over one complete scan period - 20 iterations) Verify: ESAMS values match the independently calculated values. Result: OK
27-4	Objective: Check angle demodulator output for a stationary target signal. Procedure: Set scan frequency and monopulse signal values at: RESCFQ = 34.7 SGSV = (5.0, 0.0) SGDVA = (0.0, 0.0) SGDVE = (3.0, 0.0) 1. Stop in subroutine DEMOD2 2. Stop on line 135 3. Examine variables SGDVA, SGDVE, AZERR and ELERR 4. Compare to pre-calculated values 5. Go to 1 (Repeat process over one complete scan period - 20 iterations) Verify: ESAMS values match independently calculated values. Result: OK
27-5	Objective: Check angle demodulator output for a moving target signal. Procedure: Set scan frequency and monopulse signal values at: RESCFQ = 34.7 Target range = 5000.0 m, speed = 500.0 m/s. 1. Stop in subroutine DEMOD2. 2. Stop on line 135. 3. Examine variables SGDVA, SGDVE, AZERR and ELERR. 4. Compare to pre-calculated values. 5. Go to 1. (repeat process over one complete scan period - 20 iterations) Verify: ESAMS values match independently calculated values. Result: OK

TABLE 2.27-5. Software Test Cases for Angle Tracking. (Contd.)

Test Case ID	Test Case Description
27-6	Objective: Check angle demodulator output under zero-sum (cross-eye) geometry. Procedure: Set scan frequency and monopulse signal values at: RESCFQ = 34.7 Signal 1: SGSV = (2.0, 5.0) SGDVA = (1.0, 2.5) SGDVE = (0.0, 0.0) Signal 2: SGSV = (-2.0, -5.0) SGDVA = (-1.0, -2.5) SGDVE = (0.0, 0.0) 1. Stop in subroutine DEMOD2. 2. Stop on line 135. 3. Examine variables SGDVA, SGDVE, AZERR and ELERR. 4. Compare to pre-calculated values. 5. Go to 1. (repeat process over one complete scan period - 20 iterations) Verify: ESAMS values match independently calculated values. Result: The zero-sum test case led to a divide by zero error since the sum channel signal was zero magnitude.
27-7	Objective: Check composite sum and difference channel signal calculation. Procedure: 1. Stop in subroutine SUMDIF. 2. Stop on line 103. 3. Examine variable SUMTOT, AZTOT, and ELTOT. 4. Compare to pre-calculated values. Verify: ESAMS values match independently calculated values. Result: OK
27-8	Objective: Check normalized sum and difference channel signals. Procedure: 1. Stop in subroutine SUMDIF. 2. Stop on line 143. 3. Examine DETAZ and DETEL. 4. Compare to pre-calculated values. Verify: ESAMS values match independently calculated values. Result: OK

TABLE 2.27-5. Software Test Cases for Angle Tracking. (Contd.)

Test Case ID	Test Case Description
27-9	Objective: Check angle error computation for a set of target signal values. Procedure: Set monopulse signal values at: Case 1: SKSGSV = (0.0, 0.0) SKSDFA = (0.0, 0.0) SKSDFE = (0.0, 0.0) Case 2: SKSGSV = (0.0, 0.0) SKSDFA = (0.00001, 0.0) SKSDFE = (-0.00001, 0.0) Case 3: SKSGSV = (5.0, 0.0) SKSDFA = (0.0, 0.0) SKSDFE = (3.0, 0.0) Case 4: SKSGSV = (3.0, 5.0) SKSDFA = (1.5, 3.0) SKSDFE = (0.0, 0.0) Case 5: SKSGSV = (4.5, -4.5) SKSDFA = (-1.5, 1.5) SKSDFE = (-1.5, 1.5) 1. Stop in subroutine SUMDIF. 2. Stop on line 147. 3. Examine variables SAZERR and SELERR. 4. Compare to pre-calculated values. 5. Go to 1. (repeat process for each target signal case) Verify: ESAMS values match independently calculated values. Result: For small signal cases, angle errors of about 10^{23} occur when the magnitude of the sum channel signal falls below 10^{-30}.

TABLE 2.27-5. Software Test Cases for Angle Tracking. (Contd.)

Test Case ID	Test Case Description
27-10	Objective: Check angle error computation for the zero-sum (cross-eye) geometry. Procedure: Set monopulse signal values for two targets at: Signal 1: SKSGSV = (2.0, 5.0) SKSDFA = (1.0, 2.5) SKSDFE = (0.0, 0.0) Signal 2: SKSGSV = (-2.0, -5.0) SKSDFA = (-1.0, -2.5) SKSDFE = (0.0, 0.0) 1. Stop in subroutine SUMDIF. 2. Stop on line 147. 3. Examine variables SAZERR and SELERR. 4. Compare to pre-calculated values. Verify: ESAMS values match independently calculated values. Result: OK

TABLE 2.27-5. Software Test Cases for Angle Tracking. (Contd.)

Test Case ID	Test Case Description
27-11	Objective: Check servo response for constant drive input. Procedure: Input series: Case 1. Zero input-zero error: BOREAZ = 0.000 BOREEL = 0.000 TIME AZMZAN ELMZAN 0.0000 0.00000 0.00000 0.0153 0.00000 0.00000 0.0306 0.00000 0.00000 Case 2. Zero input-nonzero error: BOREAZ = 0.100 BOREEL = 0.000 TIME AZMZAN ELMZAN 0.0000 0.00000 0.00000 0.0153 0.00000 0.00000 0.0306 0.00000 0.00000 Case 3. Nonzero input-nonzero error: BOREAZ = 0.025 BOREEL = 0.000 TIME AZMZAN ELMZAN 0.0000 1.00000 0.00000 0.0153 1.00000 0.00000 0.0306 0.00000 0.00000 1. Stop in subroutine SVOEXC. 2. Stop on line 244. 3. Examine variables AZMZAN, ELMZAN, BOREAZ and BOREEL. Verify: Reasonable output response. Result: OK
27-12	Objective: Check servo impulse response for forced response cases. Procedure: Input series: BOREAZ = 0.000 BOREEL = 0.000 TIME AZMZAN ELMZAN 0.0000 0.00000 0.00000 0.0153 2.00000 0.00000 0.0306 0.00000 0.00000 0.0459 0.00000 0.00000 0.0612 0.00000 0.00000 1. Stop in subroutine SVOEXC. 2. Stop on line 244. 3. Examine variables AZMZAN, ELMZAN, BOREAZ and BOREEL. Verify: Reasonable output response. Result: Slight drift was noticed in forced response cases, this drift was considered negligible.

TABLE 2.27-5. Software Test Cases for Angle Tracking. (Contd.)

Test Case ID	Test Case Description
27-13	Objective: Check servo response for an oscillatory input. Procedure: Input series: BOREAZ = 0.000 BOREEL = 0.000 TIME AZMZAN ELMZAN 0.0000 0.00000 0.00000 0.0153 2.00000 0.00000 0.0306 2.00000 0.00000 0.0459 0.00000 0.00000 0.0612 0.00000 0.00000 0.0765 0.00000 0.00000 0.0918 -2.00000 0.00000 0.1071 -2.00000 0.00000 0.1224 0.00000 0.00000 0.1377 0.00000 0.00000 1. Stop in subroutine SVOEXC. 2. Stop on line 244. 3. Examine variables AZMZAN, ELMZAN, BOREAZ and BOREEL. Verify: Reasonable output response. Result: Slight drift was observed in response, this drift was considered negligible.
27-14	Objective: Check first-time-through calculations. Procedure: This test is performed on the first entry into subroutine SVOEXC. 1. Stop in subroutine SVOEXC. 2. Stop on line 134. 3. Examine variable KFIRST (KFIRST should equal 1). Verify: Value of KFIRST. Result: OK
27-15	Objective: Check dead zone logic. Procedure: In an off-line run, set variable PJRS = 27.43 1. Stop in subroutine SVOEXC. 2. Stop on line 151. 3. Examine variable ZONRAD (ZONRAD should be greater than PJRS). 4. Step to next line of executable code (should be line 154). Verify: ESAMS values match independently calculated values. Result: OK

TABLE 2.27-5. Software Test Cases for Angle Tracking. (Contd.)

<table>
<tr><th>Test Case ID</th><th>Test Case Description</th></tr>
<tr><td>27-16</td><td>Objective: Check first-time-through logic

Procedure:

This test is performed on the first entry into subroutine ANTPOI.

1. Stop in subroutine ANTPOI.
2. Stop on line 102.
3. Examine variable KFIRST (KFIRST should be equal to 1).
4. Step to the next executable line of code (should be line 106).
Verify:

1. KFIRST is equal to 1.
2. Proper code execution.
Result: OK</td></tr>
<tr><td>27-17</td><td>Objective: Check change of step size logic.

Procedure:

This test is performed off-line in two passes through the subroutine. The step size is changed before the second pass. Data is set as follows:

AZSVO1 = 0.2

ELSVO1 = 0.3

On pass 1:

GDT = 0.0002

1. Stop in subroutine ANTPOI.
2. Stop on line 160.
3. Examine variables AZSV01, ELSVO1, RSCA1-RSCA7, and note values.
On pass 2:
GDT = 0.0001
4. Stop in subroutine ANTPOI.
5. Stop on line 160.
6. Examine variables listed above to check that AZSV01, RSCA1, and RSCA2 have changed appropriately, while the others have remained constant
Verify: ESAMS values match independently calculated values.

Result: OK</td></tr>
<tr><td>27-18</td><td>Objective: Check Servo coefficients.

Procedure:

1. Stop in subroutine ANTPOI.
2. Stop on line 160.
3. Examine variables RSCA1, RSCA2, RSCA3, RSCA4, RSCA5, RSCA6, and RSCA7.
4. Compare to pre-calculated values.
Verify: ESAMS values match independently calculated values.

Result: OK</td></tr>
</table>

2.27.5 Conclusions and Recommendations

2.27.5.1 Code Discrepancies

No major errors were found.

2.27.5.2 Code Quality and Internal Documentation

Code quality is generally good, although two additional conditional statements are recommended.

In subroutine DEMOD2, the slight chance of a divide by zero can be avoided entirely by adding a conditional around line 86 that would limit small amplitude sum channel signals.

In subroutine SUMDIF, a conditional to avoid a sum channel signal of magnitude less than 10^{-30} would eliminate unreasonably large angle errors.

Internal documentation is adequate.

2.27.5.3 External Documentation

There is no external documentation for ESAMS 2.6.2. Therefore, the external documentation for 2.5 was used. Other than choosing which missile/radar to use, there is no direct user interface to angle track FE, therefore, it is not discussed in the User's Manual.